Institution: University of Strathclyde

Unit of Assessment: 13

Title of case study: Human safety and economic benefits from commercialisation of a unique gas detection product

1. Summary of the impact (indicative maximum 100 words)

New commercial gas sensing technology developed from research at the University of Strathclyde brings extensive technical, operational, safety and cost benefits to applications such as mine safety and leak detection in methane production, storage, piping and transport systems. World-wide commercial sales (in Japan, China and the USA) began in late 2010 through a spin out company, OptoSci Ltd. Sales are growing and have amounted to a total of £250k since launch plus a customisation contract for £193k, leading to jobs sustainability and growth. In addition to economic impacts, the technology also brings health and safety benefits in the gas distribution and mining industries through human safety assurance in the event of gas leaks / build up.

2. Underpinning research (indicative maximum 500 words)

Context*:* Products based on hot wire pellistor technology currently dominate the gas safety market, particularly for methane detection. However, they suffer from the requirement to have electrical power at every sensor head, the need for regular re-calibration and maintenance of the sensors (monthly for some applications) and sensor head degradation leading to a need for frequent replacement (every 6-12 months depending on the application). Following a gas contamination or leak incident (usually methane), all electrical power is shut off to the incident zone (in mining that means the entire underground complex), leaving the operators and rescue teams blind to the gas conditions (particularly detrimental in mining).

Our research has led to the development and commercialisation of a multi-point optical methane detection system where electrical power is not required at the sensor heads. In an emergency, the system continues to inform the operators and rescue teams of the gas conditions in the incident zone. In addition, significant technical and operational benefits accrue from the self-calibrating and highly reliable sensor heads (long periods between maintenance and little need for replacement).

Key Research Findings: The research, carried out entirely in the department of Electronic and Electrical Engineering (EEE) at the University of Strathclyde, which led to the new commercial product, centred on two distinct areas, conducted from 1995 to 1998 and from 2002 to 2009:

1. From 1995 to 1998, research in the EEE Department at Strathclyde led to the ground breaking development and first ever demonstration of large scale, multi point, optical gas detection systems with no need of electrical power at the sensing points. Single point, free space tuneable diode laser spectroscopy (TDLS) for gas detection and concentration measurement was available, but of course required electrical power for the laser and receivers. Our research extended this technology to large scale multi-point systems based on optical sensing cells addressed by single mode optical fibres in a multi-branch or long distance linear network [References 1 & 2]. With the development and refinement of this new technology, up to 300 points can now be addressed from a single laser over a wide area involving distances up to 20km. The laser and optical receivers are housed together in a control room remote from the potential gas incident zone and no electrical power is required at the sensor heads, in the fibre optic network or indeed anywhere in the potential incident zone.

The insight and challenges in the research were related to the input / output optical fibre interfacing to the sensing cells (detection zones), the multi-path optical interference resulting from the collimating and collection lenses, and the data acquisition and signal processing systems to address such large sensing point arrays in parallel and quickly. The fibre interfacing was refined to minimise optical loss through the cell and to minimise the optical interference and the associated noise arising at the receivers [References 3 & 4]. The optical interference noise and all other sources of optical and electronic noise were fully characterised and minimised to a tolerable level. Optical power losses through the whole system were minimised through modelling and experimentation. These achievements along with the later development of fast update, calibration-free data acquisition and analysis systems (see research area 2) enabled the system to achieve the number of sensing points and area extent noted above. The initial work on this and its ground breaking outcomes (multi-point wide area coverage and no requirement of electrical power at the sensors) were achieved in 1995 to 1998 via a DTI Link project called OMEGA [Grant A Section 3].

Key researchers: This research programme was carried out wholly within the EEE Department at Strathclyde and was led by Professor Brian Culshaw, PI on Project (member of academic staff, 1984 to 2010) and Professor George Stewart, Co-I on Project (member of academic staff 1986 to 2011).

2. From 2002 to 2009 our research led to the development, analysis and experimental validation of novel, calibration-free techniques in TDLS with wavelength modulation (WM) that, for the first time, allowed absolute gas absorption line-shapes to be recovered from wavelength modulation spectroscopy (WMS) measurements. This innovation resulted in calibration-free, highly accurate, simultaneous measurement of gas concentration and pressure using WMS techniques. Full mathematical models of the signal generation and recovery algorithms in relation to the spectroscopic line-shapes were developed and reported, along with full experimental investigations and validation of the models and techniques [References 5 & 6].

Key researchers: This research work was led by Prof. Walter Johnstone (member of academic staff 1986 – present) and Prof. George Stewart (1986-2011), initially through their supervision of two EPSRC CASE PhD students: Kevin Duffin (sponsored by OptoSci Ltd. – 2002-05 and then research assistant, 2006-09) and Andrew McGettrick (sponsor Rolls-Royce, 2004-7). It was refined for engineering application under a DTI project involving OptoSci Ltd. called "Remote atmospheric laser methane sensing (REALMS)" [Grant B Section 3, 2006-09; PI: W Johnstone]. Dr Duffin was then employed by OptoSci Ltd. in a Research and Development role from 2009 to 2013. This work achieved the freedom from calibration and accuracy of measurement required in the final system.

The above research achievements were essential for the development and eventual realisation of the unique commercial product, manufactured by OptoSci Ltd. The key outcomes of the research, the cell engineering to achieve optical fibre in / out coupling with low loss and low noise [References 1 & 2], the extension of single point TDLS to large scale multi-point systems [References 3 & 4] and the realisation of new calibration-free techniques for absolute gas parameter measurement [References 5 & 6], form the technical essence, novelty and advantages of the commercial multi-point gas sensing product.

3. References to the research (indicative maximum of six references)
References 1, 3 and 6 are selected to indicate the quality of the research. Reference 6 is included in REF 2014 submission for UoA13.

1. B. Culshaw, G. Stewart, F. Dong, C. Tandy and D. Moodie, "Fibre Optic Techniques for Remote Spectroscopic Methane Detection – from Concept to System Realisation," Sensors and Actuators B: Chemical, Vol. 51, pp 25-37, May 1998.

2. G. Stewart, C. Tandy, D. Moodie, M. A. Morante and F. Dong, "Design of a Fibre Optic Multi-Point Sensor for Gas Detection," Sensors and Actuators B: Chemical, Vol. 51, pp 227-232, August 1998.

3. W. Jin, Y. Z. Xu, M. S. Demokan and G. Stewart, "Investigation of interferometric noise in fibre optic gas sensors with use of wavelength modulation spectroscopy", Applied Optics, Vol 36, No28, October 1997, pp 7239-7246.

4. G. Stewart, A. Mencaglia, W. Philp, and W. Jin, "Interferometric signals in fibre optic methane sensors with wavelength modulation of the DFB laser", IEEE Journal Lightwave Technology, Vol 16, No1, January 1998, pp 43-53.

5. K. Duffin, A. J. McGettrick, W. Johnstone, G. Stewart and D. Moodie, “Tunable Diode Laser Spectroscopy with Wavelength Modulation: a Calibration-Free Approach to the Recovery of Absolute Gas Absorption Line-Shapes”, IEEE Journal of Lightwave Technology, Vol. 25, No. 10, pp 3114-3125, October 2007. DOI: 10.1109/JLT.2007.904937

6. J. McGettrick, K. Duffin, W. Johnstone, G. Stewart and D. Moodie, “Tunable diode laser spectroscopy with wavelength modulation: a phasor decomposition method for calibration-free measurements of gas concentration and pressure”, IEEE Journal of Lightwave Technology, Vol. 26, No. 4, pp 432-440, February 2008. DOI: 10.1109/JLT.2007.912519

Other evidence for quality of research (grants, patents etc.).
Grant A: Prof Brian Culshaw (PI) and Dr George Stewart (CoI), “Optical Methane Gas Analyser (OMEGA)”, a DTI Link programme grant via EPSRC (Ref. GR/K53833/01), Dec 1995 to May 1998.
Grant B: Prof. Walter Johnstone (PI) “High power fibre laser systems for remote gas detection” later to become “Remote Atmospheric Laser Methane Sensor (REALMS)” a DTI Technology Programme grant (Ref. TP/4/NGL/6/1/22352), March 2006 to Feb 2009).

4. Details of the impact (indicative maximum 750 words)
Process of from research to impact: The research, proof of concept and development to engineering operation were entirely achieved within the Strathclyde University research team – the Centre for Micro-systems and Photonics (CMP) in the EEE Department. The work was funded by the two DTI programmes noted in section 3 and supported by two EPSRC CASE studentships (Duffin and McGettrick noted above). Our partners (including OptoSci Ltd.), with CMP support, carried out the engineering development to prototype level and implemented the further development (OptoSci only) to full commercial product including the necessary field trials and qualification. OptoSci Ltd. worked in partnership with the research group generating the key outcomes during the entire process of basic research through technology transfer to commercial product, and continues to do so for future products arising from similar research. OptoSci Ltd. was a partner in the DTI Link project, OMEGA, in which the multi-point system was initially developed. The company also sponsored the PhD student, Kevin Duffin, and was a partner in the DTI REALMS project in which the calibration free algorithms were developed.

Nature of the impact: The benefits of this technology are due primarily to the fact that no power is required at the sensor head, making the system intrinsically safe. Electrical shut down in an emergency situation (particularly crucial for mining) does not affect the performance of the multi-point optical detection system, which continues to inform the operators and rescue teams of the gas conditions in the incident zone. This brings enormous safety benefits and informs and widens the range of intervention / rescue options. Other benefits are the economic impacts arising from expansion of OptoSci’s business through the new product line, creating employment, international sales, profits to shareholders and a reduction in costs to industry, where the new technology has been adopted. Other commercial companies are now trying to emulate multi-point systems using optical fibre networks, but, to the best of our knowledge, none has been successful to date.

1. Economic benefits: The most immediate impact is economic. The technology has been fully adopted by OptoSci Ltd., commercial products have been developed (Source A) and sales have been made, thus supporting existing jobs and leading to job creation (three new engineering jobs since 2009 with more anticipated in the coming year). Barriers to sales in safety critical markets are high, with differing qualifications required in different countries, and conservatism in the industry regarding the introduction of new, unproven technologies being the main obstacles. Hence, significant early sales after product launch are unusual. Despite such barriers, sales, starting in late 2010 and driven by the technical, operational and cost benefits of the new products, have reached a total of £250k (including export sales to Japan, Hong Kong, China and the USA). In addition, a contract worth £193k has been signed (May 2013), to customise and deliver systems over the coming year to a consortium of the UK gas distribution networks including Scotia Gas Networks, Northern Gas networks, National Grid Gas Networks and Southern Gas Networks (Source B). Given the increased commercial sales and business growth from the new product range, the shareholders, directors and employees of OptoSci Ltd. are the immediate beneficiaries in terms of business / employment sustainability and growth. A researcher from EEE at Strathclyde was employed by OptoSci from 2009-13 to support the commercial activities arising from the research outcomes. A second researcher from EEE at Strathclyde is now employed by the company in this role. Two further engineering employees have been appointed so far to support the new product range and further appointments are planned over the coming year.

In addition, economic benefit accrues to companies and organisations involved in mining and gas processing sectors through the technical and operational benefits of the technology. The Director of OptoSci has stated that the Strathclyde technology "*brings significant and unique human safety benefits to mining and gas (methane) production, storage, piping and transport systems. Other benefits to the purchaser include low cost of ownership through high reliability (little need for maintenance) and consistent accuracy in operation. We believe that this product / technology is vastly superior to any gas sensing products currently used for the detection of methane in mines etc. As such, it is the focus for all future business growth within the company*." (Source B).

2. Reduction in Costs to Industry: Elimination of the need to re-calibrate the sensor heads and their high reliability results in long periods between maintenance and little need for head replacement. Ownership costs are therefore very low. Several systems have been in operation, in situ, for more than two years with no maintenance and zero head replacement. The above coupled technical, safety, operational and cost benefits have driven global interest.

3. Improvements to detection of methane, and human safety: In addition to commercial and economic benefits, impact accrues from the applications to human health and safety assurance via the widespread need for detection of hazardous gases. This is especially important for methane in mines, tunnels (e.g. subway tunnels), gas (methane) production, and associated storage, piping and transport infra-structure. In particular, the sensor is designed to operate continuously following emergency electrical shut-down to an incident zone, widening intervention / rescue options. Hence, the benefits to the wider global industries involved in these sectors and to society in general are substantial in reach. High profile purchasers of systems include Tokyo Gas, Hong Kong and China Gas Co., Chengdu Gas Co. (all for sub-city gas distribution tunnels / ducts), Hainan Minsheng Gas Co. (for liquid natural gas storage sites), Tiandi Automation Co. Ltd. (largest mine safety systems integrator in China) and Alpha Natural Resources (third largest coal mining company in the USA). To put the significance of the new technology in context, in China alone over 3000 lives are lost annually to monthly occurring methane explosions in mines.

4. Wider applications: Strathclyde University, OptoSci Ltd and Rolls-Royce are developing the same techniques for process monitoring and emissions control in gas turbine (aero) engines and fuel cells. Impact will accrue from low carbon gains via more efficient fuel cells and better fuels for aero engines with concomitant reduction in emissions. This has led to a new, high technology, gas measurement product with first sales by July 2103 of £25k to Rolls-Royce Fuel Cell Systems Ltd.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. Details of the products can be viewed on the company's web-site www.optosci.com
B. The Operations Director, OptoSci Ltd. has provided a statement to support the claim(s) that …

- The research outcomes described above gave rise to, and form the essence of OptoSci's flag ship product line of multi-point gas sensing systems.
- The programmes and processes outlined above resulted in the transfer of this technology into the company and on into the development of commercial products.
- Sales of the product have reached a total of £250k (to the range of customers noted above) plus a signed contract valued at £193k to customise and deliver systems to a consortium of UK gas distribution networks.
- Sales to high profile, large organisations in Japan, China and the USA.